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Idukki Reservoir Break Analysis

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Abstract:-- **Idukki reservoir is a part of the Idukki Hydroelectric Project and comprises of Idukki Arch Dam, Kulamavu Dam and Cheruthoni dam. The two reservoirs- Mullaperiyar Dam and Idukki reservoir together form 24 per cent of Periyar's catchment. This study is aimed to evaluate the wave which forms when water from the Mullaperiyar hits the water column of the Idukki reservoir that could overtop the Cheruthoni Dam and how it affects the Kulamavu dam which is 22km apart from Cheruthoni dam, Kerala, India. These dams are operational since 1976 and 1977 respectively. It is important to examine the effect of water that rushes into it at the time of emergency and the magnitude of kinetic energy at the time of breaching. The present study includes the dam-break flood analysis of the Mullaperiyar dam up to the Idukki reservoir. This project is an extension of it.**

Dam break failures are often caused by overtopping of the dam due to inadequate spillway capacity during large inflows into the reservoir from heavy rainfall-generated runoff. Dam failure may also be caused by seepage or piping through the dam or along internal conduits, earthquake and landslide generated waves in the reservoir. For a cascade of dams, the breaking of one dam may cause subsequent damage to other dams located downstream due to their overtopping.

Partial or catastrophic failure of a dam leading to uncontrolled release of water causes severe damages to lives and properties of people situated downstream. The effect of such a flood disaster can be mitigated to a great extent, if the resultant magnitude of flood peak and its time of arrival at different locations downstream of the dam can be estimated, facilitate the planning of emergency action measures. The most suitable instruments for the analysis and prediction of a dam break flood are mathematical hydrodynamic simulation models. These models can be used for the prediction of dam breach flood hydrograph and its routing through the downstream valley to obtain the time series of discharge and water level at different locations of the valley. The present study includes the dam-break flood analysis of the Mullaperiyar dam up to the Idukki reservoir.

Index Terms:- Arch-gravity dams

I. INTRODUCTION

Idukki reservoir is a part of the Idukki Hydroelectric Project and comprises of Idukki Arch Dam, Kulamavu Dam and Cheruthoni dam. This study is aimed to evaluate the wave which forms when water from the Mullaperiyar hits the water column of the Idukki reservoir that could overtop the Cheruthoni Dam and how it affects the Kulamavu dam that is 22km apart from Cheruthoni dam, Kerala, India. These dams are operational since 1976 and 1977 respectively. It is important to examine the effect of water that rushes into it at the time of emergency and the magnitude of kinetic energy at the time of breaching. The present study includes the dam-break flood analysis of the Mullaperiyar dam up to the Idukki reservoir. This project is an extension of it.

Dam break failures are often caused by overtopping of the dam due to inadequate spillway capacity during large inflows into the reservoir from heavy rainfall-generated runoff. Dam failure may happen by seepage or piping through the dam or along internal conduits, earthquake and landslide generated waves in the area. For a cascade of dams, the breaking of any one of them may cause subsequent damage to others located downstream due to their overtopping.

Partial or catastrophic failure of a dam leading to uncontrolled release of water causes severe damages to lives and properties of people situated downstream valley. The effect of such a flood disaster can be attenuated to a great extent if the resultant magnitude of flood peak and its time of arrival at different locations downstream of the dam can be estimated, facilitate the planning of emergency action measures. The most suitable instruments for analysing and dam-break flood prediction are mathematical hydrodynamic simulation models. These models are used to predict dam breach flood hydrograph and its routing through the downstream valley to obtain the time series of discharge and water level at different locations of the valley. The present study includes the dam-break flood analysis of the Mullaperiyar dam up to the Idukki reservoir.

2. THEORY

Dams are hydraulic structures of impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. The purposes may be Irrigation, Hydropower, Water-supply, Flood Control, Navigation, Fishing, Recreation etc. Dams have built to meet any of the above purposes or may be constructed for more than one. Dams, classified as Single-purpose and Multipurpose Dam. "The bigger the dam of patience, the worse will be the flood when it breaks."

A gravity dam together with an arch dam make an arch-gravity dam for areas with a massive amount of water flow but it has less material available for a pure gravity dam. The inward compression of the dam by the water reduces the horizontal force acting on the dam. Hence, the gravitation force required for the dam is weak, i.e. the dam need not be so massive. That enables thinner dams and saves resources efficiently.

Dams are water bombs built across the rivers, these dams have to maintain periodically to avoid water bomb disasters.

1.2 Required Measurements

There are a few measurements that you need to know

- Surface area
- Maximum depth

SURFACE AREA:

• The surface area of a dam is the product of length and width.

Example: 30 metres X 50 metres = 1500 m2.

• This is for square or rectangular dams. Primarily most dams are square or rectangle, but over time there appears to become rounded. If the dam is not exactly square or accurate, round the measurements off.

VOLUME:

• With the surface area depth calculated, the volume can thus be determined:

Volume (m3) = Surface Area (m2) x Max depth (m) x 0.4 (Where 0.4 accounts for the slope on the sides of the dam)

DEPTH:

• A way to determine dam depth is to row out into the dam and lower a weighted line over the side. When the line is vertical, measure the length of the line that is needed to reach the bottom. Another way of finding the depth is the use of a pole with distances marked on it. You will need to do this at several places across the dam to find the deepest point.

• The distance between the float and the sinker will be the depth at that certain point in the dam.

2. WORK

This work mainly concentrates on the event that, if Mullaperiyar Dam that is at Tamilnadu-Kerala territory fails at its maximum capacity during a monsoon season, water rushes towards the Idukki reservoir catchment area through the Periyar River after travelling a distance of approximately 83.3kms by taking about 2hrs 8m [1]. Considering both Idukki and Mullaperiyar at their maximum capacity, a calculation has done to examine the wave which forms when the water from the Mullaperiyar hits the water column of the Idukki reservoir could overtop the Cheruthoni Dam [2]. As the water reaches the place at equal time intervals for all the three dams, being the weakest, the Kulamavu dam could not withstand the giant waves.

Dams have designed to hold the maximum amount of water at its worst conditions of earthquakes, silt sedimentation, sudden increase of water pressure during monsoon season etc. No authorities till-date have mentioned the waves that form during the hitting of water columns of Mullaperiyar and Idukki reservoir.

For this, we are considering a volcanic explosion that takes place in the deep sea that results in the formation of giant waves. Studies have found that it can form circular Tsunami waves of width 1km approaches toward the shore, but as the resulting wave has to travel a longer distance from the point of impact, the circular wavefront can be changed to plane one, which will have a shape of a cuboid [3]. Thus, the volume of the whole column can be determined using the formula of

$v = lbh$

Where,

v-volume of the column.
l-length of the column.
b-width of the column.
h-height of the column.

Now on pointing towards the Idukki reservoir, we are considering two regions of the water body.

The first region at which the Periyar River joins the reservoir, where the water from the Mullaperiyar rushes towards the Idukki Dams to form giant waves that have chances to hit the Cheruthoni dam directly. The second is a point near the Cheruthoni dam, whose path is narrower than the first point. So, this work intends to the change length of the two regions, where the width of the wave kept as a constant can lead to an increase in its height. Thus, a wave of height longer than the wave formed at the impact point will hit the dam by considering the attenuation as negligible.

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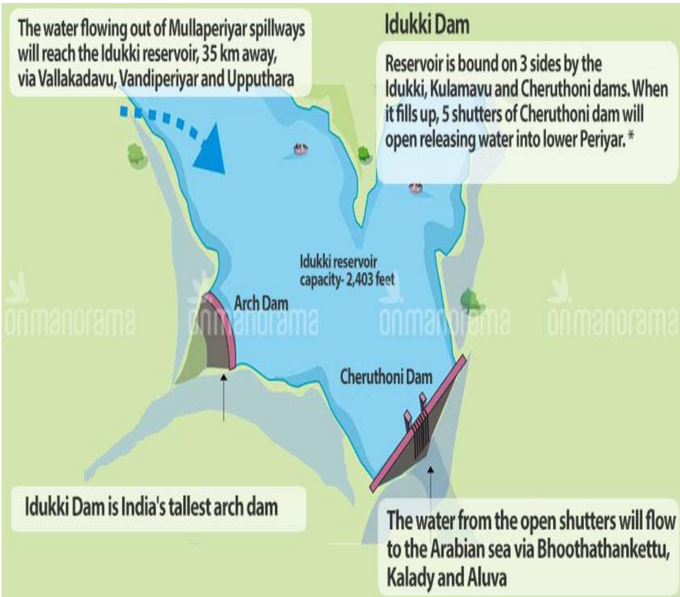

***REGION 1:**

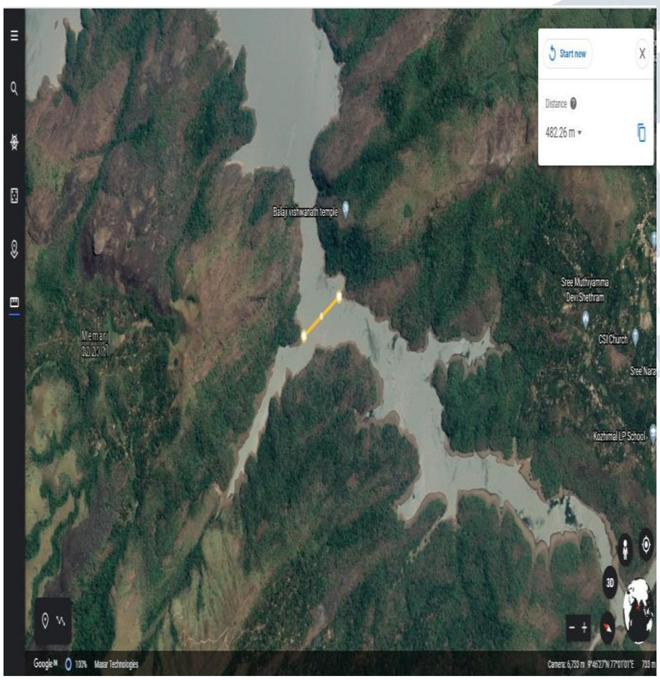

Fig.1.The region given in the above figure is the impact point of the water from Mullaperiyar Dam on the Idukki Reservoir.

The volume of the water column is given by

$$v = lbh$$
$$l = 482.6\text{m}$$
$$b = 1\text{km} = 1000\text{m}$$
$$h = 14\text{m (std. height of a wave)}$$

Thus,

$$v = 482.6 \times 1000 \times 14$$
$$= 67{,}51{,}640\, litres. \quad \ldots (1)$$

***REGION 2:**

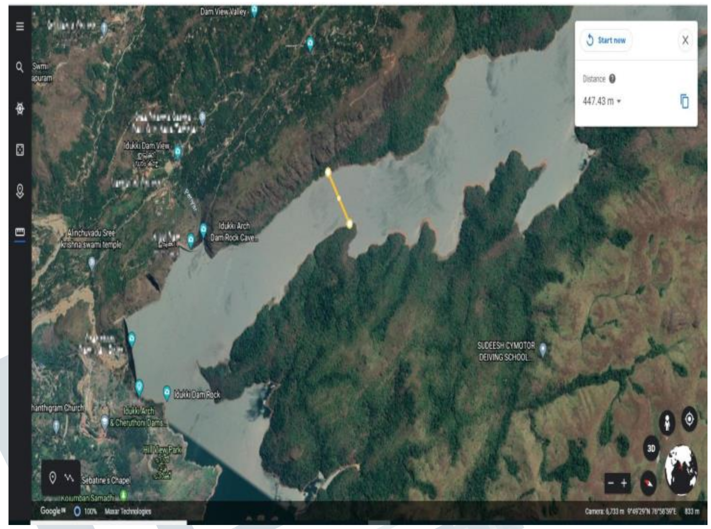

Fig.2.The region given in the above figure is a narrow region that is directed towards the Cheruthoni Dam.

The volume of the water column at this point is to be determined, but the available data are not sufficient to find it out. The volume of the water column at this point is given by

$$V = LBH \text{ At this point,}$$
$$L = 447.43\text{m}$$
$$B = 1000\text{m}$$
$$H = ?$$
$$V = 447.43 \times 1000 \times H. \quad ..(2)$$

*As we know, since the wave is propagated throughout the water body, the volume is assumed to be the same at each point on the surface of the water body.

Thus, the volume we have got in REGION 1 and REGION 2 can be considered as equal. Thus,

$$lbh = LBH$$

From (1) and (2)

$$447.43 \times 1000 \times H = 67{,}51{,}640\ litres \quad ..(3)$$

From (3)

$$H = 15.08m. \quad ..(4)$$

* Therefore, the change in height, when the wave passes through the REGION 2 can be given as

$$\Delta h = H - h$$
$$= 15.08 - 14$$
$$= 1.08m.$$

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For the water to overtop the dam, the height of the water column must be higher than the height of the dam. At extreme conditions, the water will be at its maximum permitted level, which is known as its Maximum Water Level (MWL). The calculated height of the wave formed near the dam is 15.08m. Thus, the wave height at the hitting point will be the sum of the Maximum Water Level and the wave height thus formed.

The Maximum Water Level (MWL) = 2409ft
= 734.26m.

The height of the dam structure = 2415ft
= 736.09m (from sea level).

The height of wave at hitting point on dam
= MWL+ H
=734.26 + 15.08
= 749.34m.

Height of the wave compared to the dam
= 749.34 – 736.09
= 13.25m.

From the calculation, it is found that the height of the wave formed is higher than the height of the dam structure i.e., the difference of the height of the wave with the dam structure is 13.25m (approx.).

2.1 EFFECT ON KULAMAVU DAM

The Kulamavu Dam was constructed to prevent the water escape through Kallivally, a rivulet 30km west to Idukki Arch dam. Being the weakest among the three dams, it would not withhold the giant incoming waves at the time of emergency.

The stress subjected to the dam at the time of emergency due to the heavy incoming waves consisting of silt and sediments may result in dam failure.

Kulamavu dam is a gravity masonry dam, has a dam volume of 620,300m^3. Blocks 9 and 10 on the right bank of the Kulamavu dam, is a 105 ft wide weak zone approximately at elevations 2140 and 2195 along the axis. Whereas the shear zone is highly eroded, fractured, and soft Sulphide mineralization is detected, which is a deleterious band.

When the water from the Periyar River rushes into the Idukki Reservoir, the water pressure increases with a decrease in the area it covers.

The vigorous waves continue their path even after hitting the Cheruthoni dam.

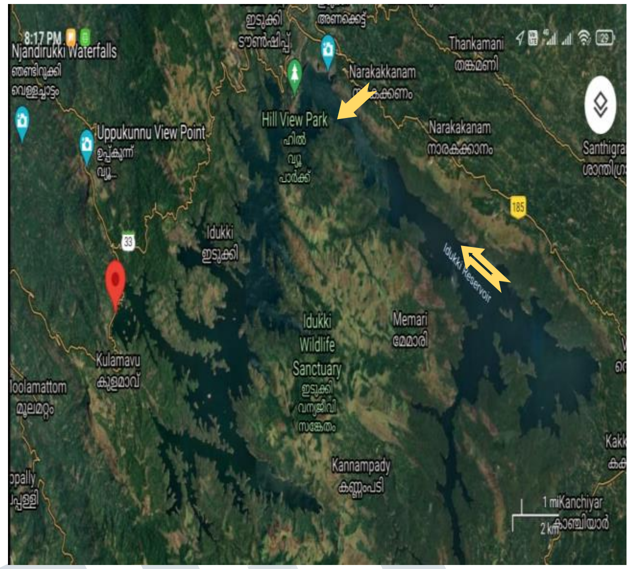


Fig.3.The water continues to flow into the Kulamavu Dam after hitting Cheruthoni Dam.

The Height of the dam structure = 2415.6168 ft
= 736.28m (from the sea level to the top of the dam)

The Height of the wave rushing into the Kulamavu Dam will be more than that of the Cheruthoni Dam since the dams are only 22km apart.

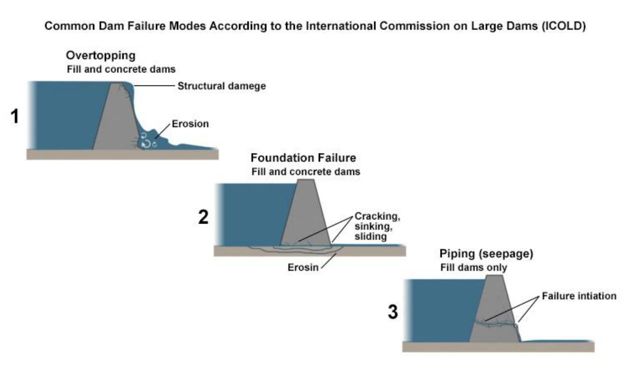
Thus,

- Height of the wave at Kulamavu Dam > Height of the wave at Cheruthoni dam.

Hence,

- Height of the hitting wave > Height of the Dam structure.

This would eventually lead to the failure of the dam, it may be due to either the leakage of the dam or can be due to the overtopping of the dam.



3. CONCLUSIONS

In this project, we tried to shed some light on the controversial issue- the breakage of the Idukki (Cheruthoni) dam in the eventuality of the collapse of the Mullaperiyar dam. According to the information we collected from the Dam safety authority officials, it is to conclude that both systems are safe, the chance of the above-described scenario is remote. But a numerical analysis based on the factors as described in [2] led us to conclude that the collapse of the Mullaperiyar dam may lead to the formation of tsunami-like waves, which can be higher than the Cheruthoni dam. It is important to note, if water overtops a gravity dam, the dam will topple.

This work is just a pilot study where the numerical calculations are not rigorous. Also, we did not calculate the kinetic energy of such waves because that calculation cannot tell us whether it will be enough to break the Cheruthoni dam. Break analysis of the Idukki arch dam, not quoted due to its complex structure. The reason for this is that the data needed to calculate the strength of a Dam is not available to us.

So, this work is only the first step in this direction. But even with this small research project, we have partially succeeded in showing the possibility of the failure of the Idukki dam. Hence it is to be concluded that the fear of the common public in this issue cannot evade out entirely.

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